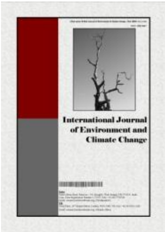

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Growth and Yield of Wheat (*Triticum aestivum* L.) as Affected by Bio-Fertilizer and Seaweed Extract

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted at crop research farm (CRF) during Rabi season 2021- 22 Department of Agronomy, SHUATS, Prayagraj (U.P), to evaluate the influence of bio-fertiliser and seaweed extract on growth and yield of wheat. The 9 treatments consisting of Seed inoculation with *Azotobacter* (ASI) 20g/kg seed and 0% application of seaweed extract (SWE) (T_1), ASI 20g/kg seed and 5% application of SWE (T_2), ASI 20g/kg seed and 7.5% application of SWE (T_3), Seed inoculation with PSB 20g/kg seed and 0% application of SWE (T_4), Seed inoculation with PSB 20g/kg seed and 5% application of SWE (T_5), Seed inoculation with PSB 20g/kg seed and 7.5% application of SWE (T_6), Seed inoculation with both *Azotobacter* and PSB 10+10g/kg seed and foliar application of 0% SWE (T_7), Seed inoculation with both *Azotobacter* and PSB 10+10g/kg seed and foliar application of 5% SWE (T_8), Seed inoculation with both *Azotobacter* and PSB 10+10g/kg seed and foliar application of 7.5% SWE (T_9), were carried in Randomized Block Design and replicated thrice. The results showed that seed inoculation with both *Azotobacter* and PSB 10+10g/kg seed and foliar application of 7.5% SWE at 30 and 60 days after sowing (DAS) (T_9) had superior values of growth parameters i.e., plant height (35.39, 82.58, 84.59 cm) and dry weight (6.19, 16.61, 22.85 g) at 60, 90 days after sowing (DAS) and harvest, respectively, and found more productive as it attained higher values of spikes/m^2 (391.67), grains/spike (53.79), test weight (40.00), as well as grain (6.68 t/ha) and straw yields (10.68 t/ha) and proved statistically

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superior over other treatments but found at par to seed inoculation with both *Azotobacter* and PSB 10+10 g/kg seed and foliar application of 5% seaweed extract (T_8).

Keywords: Azotobacter; PSB; seaweed extract; growth; yield and wheat.

1. INTRODUCTION

Wheat is the most important cereal crop for the majority of the world's population (36%) as a staple food. It is the third most important cereal after maize and rice. India ranks second amongst the wheat growing countries of the world after China in terms of area and production. Wheat is grown mostly in Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan and Bihar and these are the major wheat producing states and accounts for almost 91% of total production in India. It contains appreciable amount of nutrients including proteins, fiber and minor components including lipids, vitamins, minerals and phytochemicals, which contribute to a healthy diet. Microbial inoculants, also known as bio-fertilizers, are capable of mobilizing important nutritional elements in the soil from non-usable to usable form by crop plants through biological processes. Bio-fertilizers have grown in popularity in agriculture and food production over the last decade due to their renewable, low-cost, and environmentally friendly nature. Chemical fertilizers and pesticides have had a major impact on the climate. The use of *Azotobacter* and Phosphate solubilizing bacteria (PSB) as bio-fertilizers to complement nitrogen and phosphorus fertilizers has been extensively researched. Several crop plants grew significantly better as a result of this. Environmentally safe, sustainable farming practices include the use of microbiological fertilizers. *Azotobacter*, P-solubilizing microorganisms and other bio-fertilizers benefit crop production. While several studies have been performed in this field in different crops to research the impact of bio-fertilizers alone or in combination with other chemical fertilizers, there has been none in wheat, despite the fact that it is one of the world's most important cereal crops. As a result, the current research aims to determine the effects of *Azotobacter* and Phosphate solubilizing bacteria (PSB) on wheat yield. *Azotobacter* as a N_2 fixer and phosphate solubilizer biofertilizers (PSB) have attained good popularity among bio-fertilizers, and there has been a positive response to *Azotobacter* and PSB inoculation. Bio-fertilizers are able to fix atmospheric nitrogen in the available form for plant and have beneficial effect on plant growth by production of antibiotic [1]. These non-conventional fertilizer sources are not only cheap, but they increase soil fertility and productivity appreciably.

When *Azotobacter* and PSB are inoculated in seeds, seed germination is improved to a considerable extent and also control plant diseases due to production of anti-fungal substances. Seeds with a low germination are inoculated with *Azotobacter* to boost germination by 20–30%. The seed inoculation with *Azotobacter* inch up the uptake of nitrogen (N_2), phosphorus (P), and micronutrients like iron (Fe) and zinc (Zn) in wheat.

In addition to this, *Azotobacter* inoculation replaced upto 50% of the urea-N. PSB secrete organic acids that dissolve unavailable phosphate (PO_4^{3-}) to available forms such as HPO_4^{2-} and $H_2PO_4^-$. Besides making soluble P, P-solubilizing bacteria are involved in plant growth promotion by the production of beneficial metabolites, such as phytohormones like indole acetic acid (IAA), antibiotics or siderophores, aminocyclopropane-1-carboxylate deaminase (ACC), nitrogen fixation, zinc solubilization and antimicrobial activity against soil-borne plant pathogens [2-5]. Application of *Kappaphycus alvarezii* extracts has been reported to enhance nutrient uptake by wheat [6], which may be due to presence of many organic compounds and natural chelating compound (i.e. Manitol) in sap, which mobilize the fixed nutrients to the plant in available form. Seaweed sap is also a rich source of potassium and phosphorus. Potassium helps in regulating the water status of the plants, control opening and closing of stomata and helps in increasing photosynthetic rate, whereas phosphorus helps in root growth, and its proliferation, thereby making the plants to feed on large volume of soil in a balanced proportion [7,8] and influences the crop maturity as a whole. Besides, it also helps the photosystems to produce NADPH. In field crops, seaweed products are being used in many ways like foliar spray, soil amendments, seed primer etc. Through foliar spray, it is directly assimilated by crop foliage within few hours after application. As seed primer, it improves the establishment of the crop by can increasing the vigour and germination rate. Further, Shah et al. [6] found that application of *Kappaphycus alvarezii* seaweed extract is an alternative nutrient source to enhance yield of wheat grain by 20 and 13% respectively as well as of better quality [5]. In light of the above, this experiment was conducted to determine the effect of bio-fertilizer (*Azotobacter* and phosphate solubilizing bacteria) and leaf fertilizer of seaweed extract on wheat growth and yield.

2. MATERIALS AND METHODS

The experiment was carried out during Rabi season of 2021-22 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (U.P), India, which is located at 25^o 39' 42" N latitude, 81^o 67' 56" E longitude and 98 m altitude above the mean sea level. The experiment was conducted in Randomized Block Design consisting of 9 treatment combinations with 3 replications and was laid out with the different treatments allocated randomly in each replication viz. ASI 20g/kg seed + 0% SWE (T_1), ASI 20g/kg seed + 5% SWE at 30, 60 days after sowing (DAS)/ha (T_2), ASI 20g/kg seed + 7.5% SWE at 30, 60 (DAS)/ha (T_3), phosphate solubilizing bacteria (PSB) 20g/kg seed + 0% SWE (T_4), PSB 20g/kg seed + 5% SWE at 30, 60DAS/ha (T_5), PSB 20g/kg seed + 7.5% SWE at 30, 60 DAS/ha (T_6), ASI + PSB 10+10g/kg seed + 0% SWE (T_7), ASI + PSB 10+10g/kg seed + 5% SWE at 30, 60 DAS/ha (T_8) and ASI + PSB 10+10g/kg seed + 7.5% SWE at 30, 60DAS/ha (T_9). The uniform dose of major nutrients i.e., 120kg N, 60kg P, 40kg K was applied in all the plots. The soil of the experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.7), low in organic carbon (0.57%), available N (203.7 kg/ha), medium in available P (17.2 kg/ha) but high in available K (346.0 kg/ha). The major nutrients were applied in soil through urea, single super phosphate (SSP) and muriate of potash (MOP). Halt dose of nitrogen and full dose of P and K was applied as basal dressing and remaining quantity of nitrogen was top dressed in equal quantity at 30 and 60 DAS. Test variety (SS-303) was sown on 4th week of November 2021 with a spacing of 22.5 x 5 cm. After germination, the gaps were filled up by dibbling of seed at 10 days after sowing. Seedlings were thinned out in order to maintain spacing of 22.5 x 5 cm. Manual weeding was done with the help of khurpi at 28 and 45 days after sowing to minimize the crop weed competition. Seed was treated with bio-fertilizers (*Azotobacter* + PSB) and seaweed extract was applied two times through foliar spray at tillering and booting stages. The field was maintained in a moist condition and for this, four irrigations were provided, one as pre sowing and other at CRI, spike initiation and milking stages. The crop was harvested separately from each plot taking 1.0 m^2 area on March 29th 2022, i.e., 120 days after sowing. Thereafter, the produce from net plot was tied in bundles separately and then tagged. The tagged bundles were allowed for sun drying in field and after drying on the threshing floor, the weight of bundles was recorded for obtaining biological yield. The data were collected on plant height, plant dry weight at 30, 60, 90 DAS and at harvest but yield attributing traits namely number of spikes/m^2, number of grains/spike, test weight, grain yield, straw yield and harvest index were recorded at harvest stage

3. RESULTS AND DISCUSSION

3.1 Effect on Growth

It is evident from the data given in Table 1 that application of bio-fertilizer and seaweed extract significantly affected the growth attributing characters of wheat such as plant height and dry weight, at all time intervals except at 30 DAS. The plant height and dry weight of plant were minimum during early period of growth (30 DAS) irrespective of treatments and it was increased with time being the maximum at 90 DAS in case of plant height and harvest in case of dry weight of plant. Differentiation of node and internodes during 60 to 90 DAS and gradual increase in leaf area upto flowering i.e. 90 DAS [9] and better partitioning of photosynthates from source to sink is the reason of higher values of plant height and plant dry weight at 90 and harvest, respectively. Plant height and dry weight of plant were inferior in plots receiving only seed inoculation with PSB 20 g/kg seed with 0% SWE (T_4) and *Azotobacter* 20 g/kg seed with 0% SWE (T_1) at 60 DAS due to availability of only phosphorus and nitrogen in aforesaid treatments. However, both the traits attained maximum values in plots receiving seed inoculation with *Azotobacter* + PSB 10+10 g/kg seed with foliar application of 7.5% SWE (T_9) and proved statistically superior over other treatments except seed inoculation with *Azotobacter* + PSB 10+10 g/kg seed with foliar application of 5% SWE (T_8). Optimum availability of nitrogen and phosphorus due to non-symbiotic fixation of nitrogen by *Azotobacter* and solubilisation of unavailable phosphate to available form by PSB,

Table 1. Effect of bio-fertilizer and seaweed extract on plant height of wheat at different days after sowing (DAS)

S. No.	Treatment	Plant height (cm)			
		30DAS	60DAS	90 DAS	At harvest
1.	Azotobactor 20g/kg seed + 0% Seaweed extract	4.78	25.65	72.81	74.71
2.	Azotobactor 20g/kg seed + 5% Seaweed extract	4.73	27.13	74.43	76.47
3.	Azotobactor 20g/kg seed + 7.5% Seaweed extract	4.71	27.73	74.50	76.50
4.	PSB 20g/kg seed + 0% Seaweed extract	4.81	23.84	71.71	73.38
5.	PSB 20g/kg seed + 5% Seaweed extract	4.72	26.62	73.82	75.49
6.	PSB 20g/kg seed + 7.5% Seaweed extract	4.85	27.09	74.03	76.05
7.	Azotobactor + PSB 10+10g/kg seed + 0% Seaweed extract	4.77	28.07	78.50	80.44
8.	Azotobactor + PSB 10+10g/kg seed + 5% Seaweed extract	5.23	29.64	79.49	81.45
9.	Azotobactor + PSB 10+10g/kg seed + 7.5% Seaweed extract	4.90	35.39	82.58	84.59
	SEm±	0.51	1.05	1.07	1.06
	CD (P= 0.05)	-	3.16	3.21	3.19

Table 2. Effect of bio-fertilizer and seaweed extracton dry weight of wheat plant

S. No.	Treatment	Dry weight (g plant^{-1})			
		30DAS	60DAS	90 DAS	At harvest
1.	Azotobactor 20g/kg seed + 0% Seaweed extract	0.40	4.42	14.65	18.97
2.	Azotobactor 20g/kg seed + 5% Seaweed extract	0.39	5.15	15.08	20.71
3.	Azotobactor 20g/kg seed + 7.5% Seaweed extract	0.37	5.29	15.41	21.30
4.	PSB 20g/kg seed + 0% Seaweed extract	0.36	4.39	14.52	18.96
5.	PSB 20g/kg seed + 5% Seaweed extract	0.32	4.67	14.91	20.19
6.	PSB 20g/kg seed + 7.5% Seaweed extract	0.35	4.67	14.97	20.36
7.	Azotobactor + PSB 10+10g/kg seed + 0% Seaweed extract	0.38	5.31	15.67	21.67
8.	Azotobactor + PSB 10+10g/kg seed + 5% Seaweed extract	0.35	5.33	15.86	22.41
9.	Azotobactor + PSB 10+10g/kg seed + 7.5% Seaweed extract	0.45	6.19	16.61	22.85
	SEm±	0.03	0.24	0.28	0.51
	CD (P= 0.05)	-	0.72	0.85	1.52

Table 3. Effect of bio-fertilizer and seaweed extract on yield attributes and yield of wheat

S. No.	Treatment	Spikes/m^2	Grains/ spike	Test weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
1.	Azotobacter 20g/kg seed + 0% Seaweed extract	307.00	45.64	37.10	4.01	6.82	37.05
2.	Azotobacter 20g/kg seed + 5% Seaweed extract	339.00	47.59	38.20	5.04	8.06	38.28
3.	Azotobacter 20g/kg seed + 7.5% Seaweed extract	341.00	48.24	37.83	5.11	8.68	37.11
4.	PSB 20g/kg seed + 0% Seaweed extract	304.33	45.36	36.46	4.01	6.82	37.02
5.	PSB 20g/kg seed + 5% Seaweed extract	313.33	47.42	37.00	5.09	8.65	36.98
6.	PSB 20g/kg seed + 7.5% Seaweed extract	320.00	47.48	37.20	5.10	8.67	37.09
7.	Azotobacter + PSB 10+10g/kg seed + 0% Seaweed extract	351.67	51.35	37.93	4.89	7.82	38.44
8.	Azotobacter + PSB 10+10g/kg seed + 5% Seaweed extract	359.33	52.38	38.83	6.32	10.10	38.48
9.	Azotobacter + PSB 10+10g/kg seed + 7.5% Seaweed extract	391.67	53.79	40.00	6.68	10.68	38.50
	SEm±	10.87	0.10	0.64	0.33	0.40	1.42
	CD (P= 0.05)	32.59	2.99	1.93	0.98	1.20	-

respectively, as well as direct assimilation of essential major, secondary and micro nutrients along with cytokinins and auxins after foliar application of *kappaphycus alvarezii* (k-sap), enhanced the growth in meristematic region and consequently had superior values of growth characters. However, reverse was true in case of other treatments, therefore, they attained the inferior values of yield attributing traits. The positive effect of the application of *Azotobacter* and PSB on germination, germination percentage and plant height, has also been reported by Shaharoona et al. [10].

3.2 Effect on Yield Attributes and Yield

The perusal of data presented in Table 2 indicate that application of bio-fertilizers and seaweed extract significantly affected the growth attributing characters of wheat such as spikes/m^2, grains/spike, test weight, grain and straw yields except harvest index. The values of attributing characters were poor in plots receiving seed inoculation with PSB 20g/kg seed and 0% application of SWE (T_4) and ASI 20g/kg seed and 0% application of SWE (T_1) but these were enhanced and attained the top values in plots receiving seed inoculation with both *Azotobacter* and PSB 10+10 g/kg seed and foliar application of 7.5% SWE (T_9) and proved significantly superior over other treatments being at par to plots receiving both *Azotobacter* and PSB 10+10 g/kg seed and foliar application of 5% SWE (T_8). Superior values of growth characters (plant height and plant dry weight) due to optimal nutrition at different phenophases (Tillering, penicle initiation and grain filling stage) could be assigned the reason for superior yield attributes. These result are in close conformity to that of Murugalakshmi Kumari et al. [11].

3.3 Effect of Yield

Data given in Table 3 show that the grain and straw yields were affected by different levels of bio-fertilizer and seaweed extract. The values of both characters were minimum in plots receiving seed inoculation with PSB 20g/kg seed with no foliar application of seaweed extract followed by ASI 20g/kg seed with no foliar application of seaweed extract due to poor values of yield attributing traits. However, wheat grain and straw yields were increased by 39.9 and 36.2% when seed inoculation was done with both *Azotobacter* and PSB 10+10g/kg seed along with foliar application of 7.5% SWE in wheat at 30 and 60 DAS (T_9) as compared to seed inoculation with PSB 20g/kg seed and 0% application of SWE (T_4) being at par to seed inoculation with both *Azotobacter* and PSB 10+10g/kg seed along with foliar application of 5% SWE in wheat at 30 and 60 DAS (T_8) but found significantly superior over other treatments. Superior values of yield attributing traits under former treatments could be assigned the reason of higher yields under seed inoculation was with both *Azotobacter* and PSB 10+10g/kg seed along with foliar application of 7.5% SWE (T_9) and seed inoculation with both *Azotobacter* and PSB 10+10g/kg seed along with foliar application of 5% SWE (T_8). Similar views have also been endorsed by Yasari et al. [12] and Jadhav et al. [13]. However, reverse was true in case of other treatments which received inoculation either with *Azotobacter*/PSB or both without any foliar application of SWE.

4. CONCLUSION

In sandy loam soil (pH 7.7 with moderate fertility) of SHUATS, Prayagraj, inoculation of seeds with *Azotobacter* and Phosphate solubilizing bacteria 10+10 g/kg seed and application of 7.5% foliar fertilization with seaweed extract along with base fertilization of 120kg N + 60kg P +40kg K/ha, enhanced the growth appreciably and found more productive (10.68 t/ha) than using *Azotobacter*/PSB or both *Azotobacter* + PSB without foliar application of seaweed extract.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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